REYNOLDS CREEK

1961

SUMMARY

REPORT

1982

COOPERATIVE WATERSHED STUDY

IDAHO
1984

Acknowledgements

This report represents the combined efforts of many people over the past 20 years. Without the efforts of the Bureau of Land Management (particularly the Boise District), and the personnel of the Agricultural Research Service Northwest Watershed Research Center, this project would not have been completed. Special thanks to the Idaho State Office BLM Hydrologist for preparing the executive summary and to the ARS for preparing the general summary.

United States Department of the Interior

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September 5, 1984

Information Bulletin No. DSC-84- 126

To: All Field Officials

From: Service Center Director

Subject: Reynolds Creek Bureau of Land Management - Agricultural Research Service (BLM-ARS) Cooperative Watershed Research

The final 5-year phase of the subject research ended September 30, 1983. With printing now completed, a summary (Volume I), Comprehensive Report (Volume II), and Appendix (Volume III) are transmitted as Enclosures 1, 2, and 3.

On July 6, 1961, BLM signed a Memorandum of Understanding with ARS for use of public land in the Reynolds Creek Watershed, Boise District, for

FOREWARD

The purpose of this document is to summarize the research conducted over the past 20 years at the Reynolds Creek Experimental Watershed. This report is Volume I of three volumes. Volumes II and III were released in 1983 by the Agricultural Research Service and contain project descriptions and a detailed data summary. This volume contains a brief executive summary and a more detailed general summary of the research.

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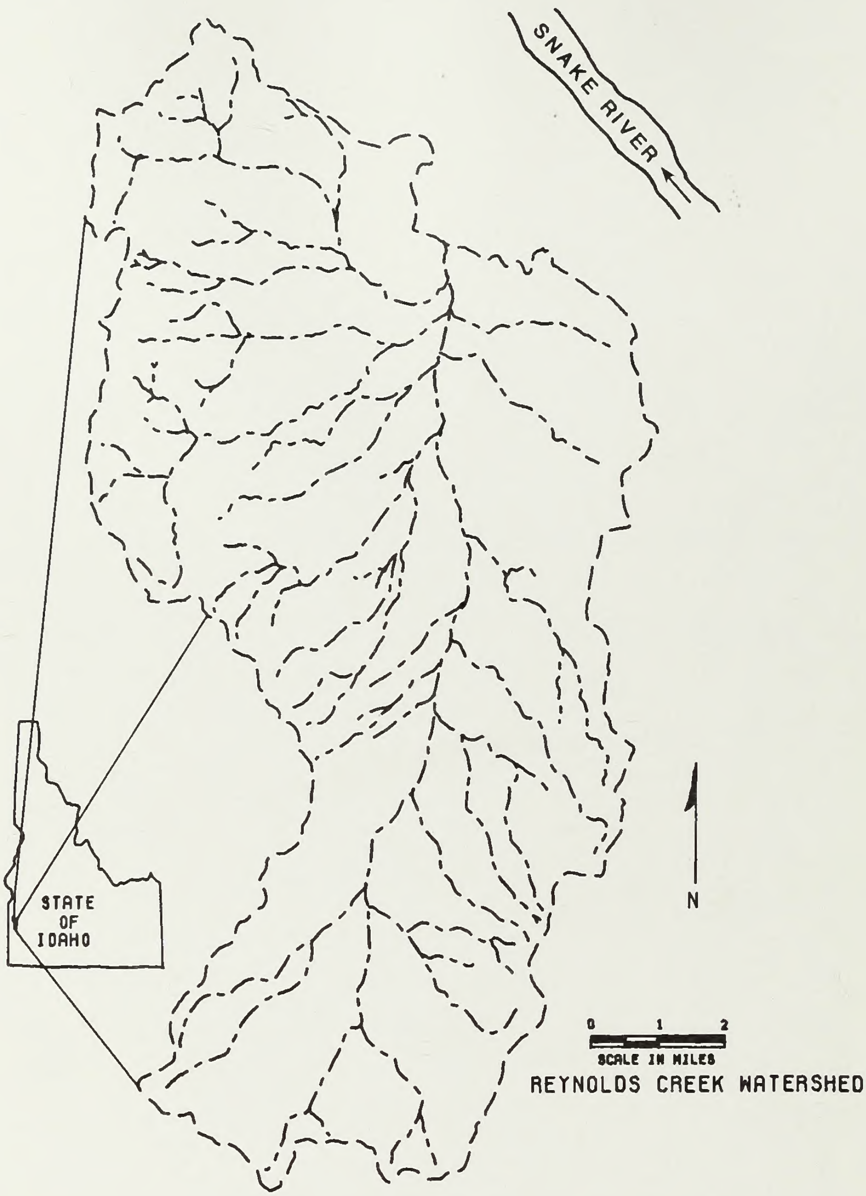
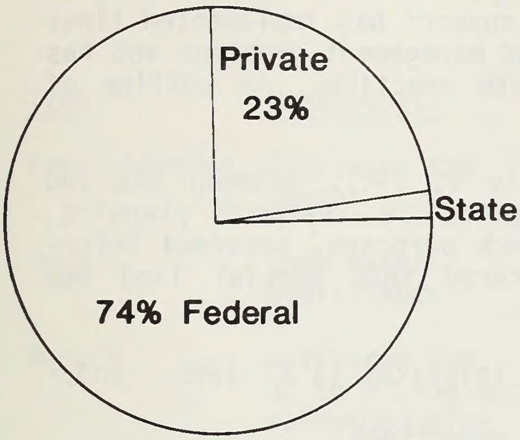
Reynolds Creek Watershed



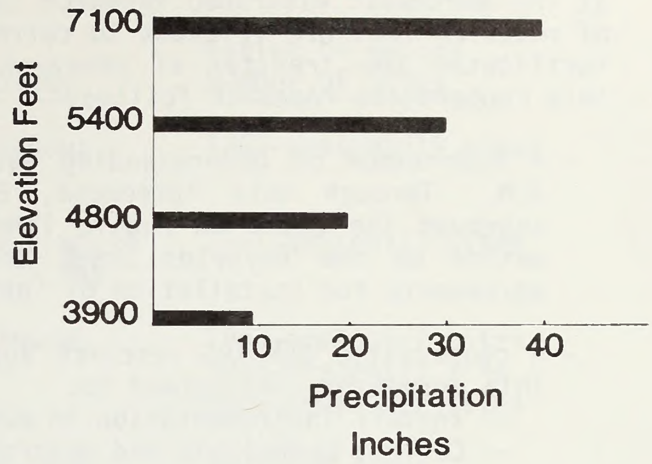
The Reynolds Creek Experimental Watershed is operated by the Northwest Watershed Research Center of the U.S. Department of Agriculture, Agricultural Research Service. Located in southwestern Idaho, the watershed has served as a rangeland watershed research center since the early 1960's, and has been the focus of research sponsored by the Bureau of Land Management (BLM) since 1969.

The Reynolds Creek watershed encompasses about 90 square miles or 57,760 acres, and is a tributary to the Snake River. The Research Center (office located in Boise, Idaho), has conducted research in hydrology, rangeland vegetation, water quality, geology, soils, and climatology.

Why Reynolds Creek?



Ownership



Vegetation Site Descriptions

Vegetation Site Name		Characteristic Habitat Type
Saline bottom	8-12"	greasewood, basin wild rye
Calcareous loam	7-10"	shadescale, budsage, Indian ricegrass
loamy	10-13"	Wyoming big sage, bluebunch wheatgrass
loamy	13-16"	Mountain big sage, Idaho fescue
Shallow claypan	12-16"	low sage, Idaho fescue
Aspen Thickett	16"+	Aspen

Variety of site descriptions found on Reynolds Creek

The Northwest Watershed Research Center was established by Congress to gain basic information on runoff characteristics, including water yield from plateau and foothill grazing areas of the northwest. The Reynolds Creek watershed was selected because of its geographic location in the northwest and its representation of the surrounding region. Reynolds Creek is primarily a rangeland watershed with a small amount of irrigated farming. The watershed has a variety of range sites resulting from its wide range of precipitation, elevations, aspects, and soils. Environmental conditions for many western rangelands are represented at Reynolds Creek. These factors make Reynolds Creek an ideal outdoor laboratory for rangeland research activities.

Research Objectives

Cooperative research with BLM is an important part of the research program at the Northwest Watershed Research Center. BLM support has implemented lines of research that are relevant to current rangeland management problems and has facilitated the transfer of research results into practice. An outline of this cooperative research follows:

- A Memorandum of Understanding was signed July 6, 1961, between ARS and BLM. Through this agreement, BLM participated in research planning, approved the entry on public land for research purposes, provided information on the Reynolds Creek area, and entered into special land use agreements for installation of instrumentation.

- A cooperative BLM-ARS research agreement was initiated in FY 1969. Under this agreement, ARS agreed to:
  - -- Install instrumentation to meet research objectives.
  - -- Collect hydrologic and watershed data.
  - -- Measure ground cover and soil moisture in support of infiltration tests and collect herbage yields by species.
  - -- Develop an infiltration model and relate parameters to soil cover complexes.
  - -- Establish a sediment-runoff relationship.
  - -- Provide people and resources to carry out studies.
  - -- Prepare research outlines and annual research reports.

In 1972, a water quality study was added to the cooperative agreement. Its objective was to characterize the water quality of a rangeland watershed as affected by grazing and irrigation diversions. Also, emphasis was given to rangeland stock water development.

The BLM-ARS cooperative agreement was renewed in FY 1974. Research topics emphasized were as follows:

Vegetation and soils	Runoff and sediment
Infiltration	Evapotranspiration
Water quality	Watershed modeling

The BLM-ARS cooperative agreement was renewed for another five years in FY 1979. The concluding year of this agreement was to prepare a comprehensive report of the Reynolds Creek cooperative research project including the watershed and hydrologic data base. The objectives of the present agreement are:

- Document watershed data bases for soils, vegetation, precipitation, runoff, soil water, water quality, and groundwater.
- Document, model, and extend into applicable areas, annual and monthly precipitation amounts.
- Develop and test procedures for soil erosion and sediment yields for applicable range sites.
- Predict management and water quality interactions.
- Develop and/or test watershed models.

In 1984 and beyond, major objectives will be to:

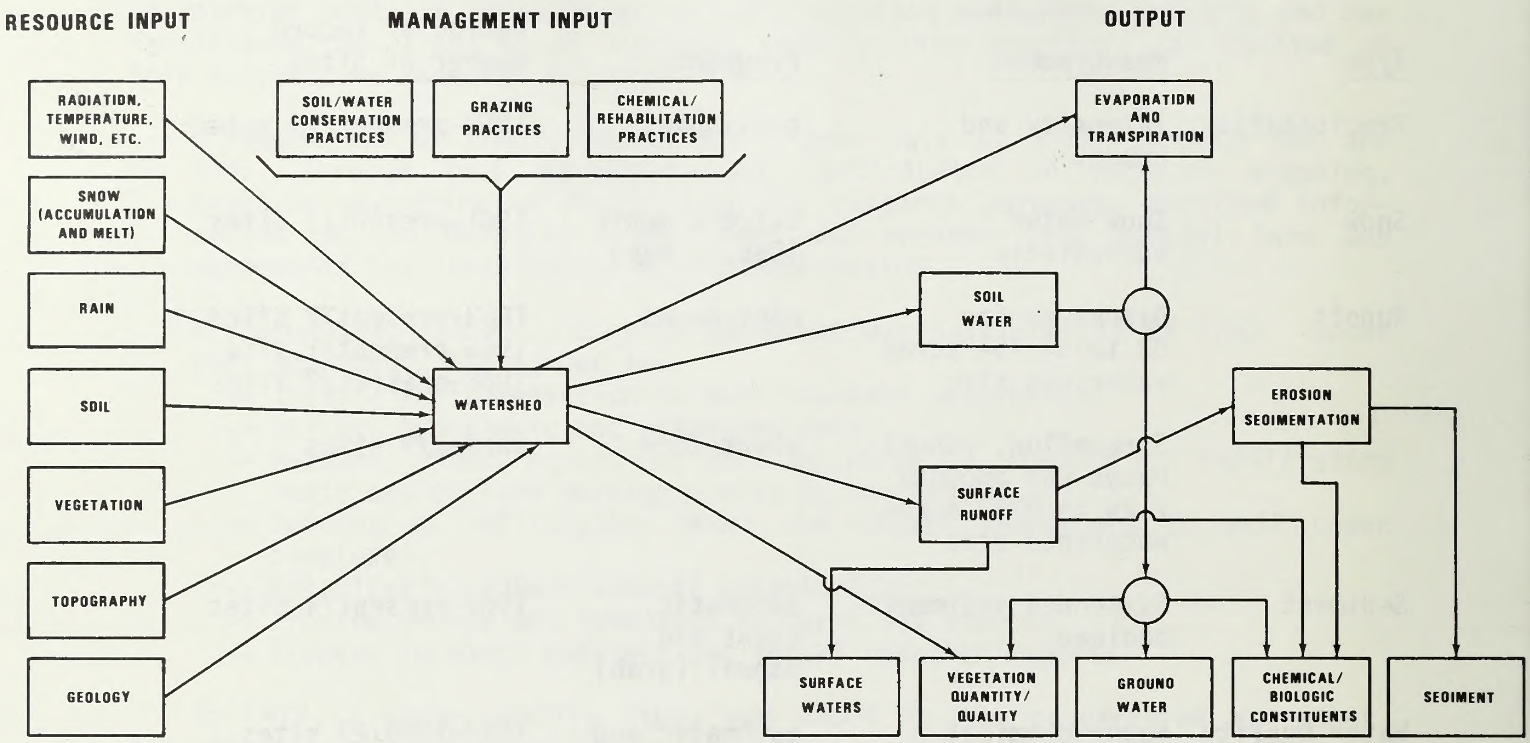
- Conduct an aggressive technology transfer program.
- Utilize the extensive data base and conduct new research at Reynolds Creek to answer specific management questions.

Type of Data Available

Type	Measurement	Frequency	Period of Record Number of Sites
Precipitation	Intensity and amount	continuous	1962-present/19 sites
Snow	Snow water equivalents	twice a month (Dec. - May)	1961-present/7 sites
Runoff	Discharge for 33 to 57,754 acres watershed size	continuous	1963-present/2 sites 1965-present/1 site 1966-present/2 sites
	Streamflow, runoff rates and amounts 2.24 to 8990 acres watershed size	short-term	varies/9 sites
Sediment	Suspended sediment bedload	automatic, event and manual (grab)	1967-present/4 sites
Water Quality	Major chemical constituents, Bacteria, pH, temperature	automatic and grab samples	1972-1980/23 sites
Vegetation	Yield cover and frequency	yearly at peak standing crop	1972-1980/9 sites
Soil Water	Content with depth	bi-weekly	1973-present/4 sites
Soils	Detailed SCS survey	once	1961-1964
	Detailed character-ization studies	21 sites	1980-1982

Other types of climatic data are available. Check with the Research Center for your particular need.

Resource Monitoring and Modeling



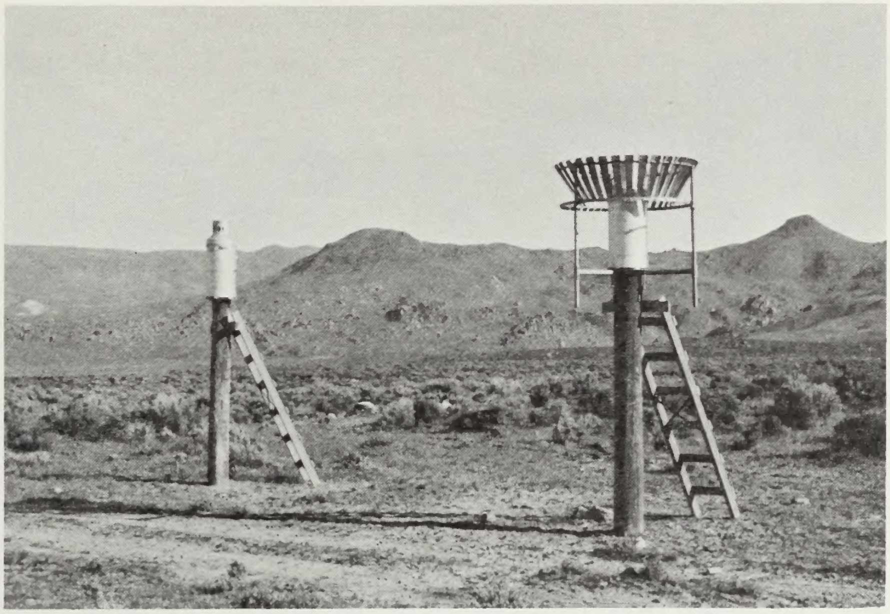
Rangeland Watershed Resource Model

Flowchart

Rangeland monitoring can be considered to be a measurement of the response to land management in one or more rangeland resource components. In the BLM, monitoring generally concentrates on the measurement of vegetation response to management actions. Four basic factors needed to analyze vegetation response are forage use, actual use, weather, and trend. Changes in vegetation and cover affect erosion, runoff, soil moisture, and water quality.

The Reynolds Creek Experimental Watershed has explored two areas of monitoring: the classical method of annual or periodic field measurements to establish a trend; and the potential for utilizing a computerized model to establish a trend. The future of computerized rangeland modeling is bright. The applications of sophisticated rangeland models to rangeland monitoring has already begun at the Northwest Watershed Research Center.

Precipitation and Climate



Typical Dual Precipitation Gage System

The precipitation gage network on the Reynolds Creek Watershed was established to measure both rain and snowfall as influenced by elevation and season. The original gage network, established between 1960 and 1961, consisted of 83 unshielded gages. In 1967-68, the network was converted to 46 dual-gage sites (shown above) in order to adequately measure snowfall. Snowfall accounts for a considerable portion of the annual precipitation since over 50 percent of the annual precipitation at low elevations and over 75 percent at high elevations occurs from November through April. Average annual precipitation varies from about 10 inches at the lower elevations (3800 feet) to 43 inches at the 7100 foot elevation.

The network was further reduced during 1976-77 to 19 sites after a thorough analysis of records to determine which gage sites best represented different areas of the watershed.

The precipitation data is used to develop procedures to predict watershed precipitation and provide input for the response of resource characteristics to management.

Procedures include equations for predicting mean annual precipitation and mean monthly precipitation as a function of elevation and slope position and a method for simulating an entire series of expected precipitation amounts for a specific site.

Streamflow and Runoff

Reynolds Creek Outlet Weir

One of the major purposes in establishing the Reynolds Creek Experimental Watershed was to obtain accurate streamflow records from a representative sagebrush watershed. The need for such records resulted in the construction of precalibrated structures similar to the Reynolds Creek outlet weir (pictured) which has a capacity of 20,000 cubic feet per second. Major floods resulting in deposition of coarse sediment upstream from the weir caused inaccurate data and required expensive sediment removal. These problems resulted in the development of the drop-box weir which has successfully operated at ten Northwest Watershed research sites.

Streamflow was measured at five long-term stations (15-20 years record) on watershed areas between 33 and 57,760 acres. Nine short-term stations operated on areas from 2.24 to 8,990 acres. Average annual runoff at the high elevations is about 20 inches; at the moderate to high elevations is nine inches; and about three inches at the Reynolds Outlet.

Results indicate that annual maximum floods at elevations above 6000 feet are normally from spring snow melt, while floods below this elevation are from summer thunderstorms, spring snow melt, and/or winter rainfall. Winter rainfall on snow and frozen ground can produce severe flooding at low to mid elevations. The data collected has produced better methods to estimate the flood frequencies and amounts for various size watersheds. A useful application of the weir has been the improvement in design for culverts, bridges, spillways, and other drainage devices.

Erosion and Sediment

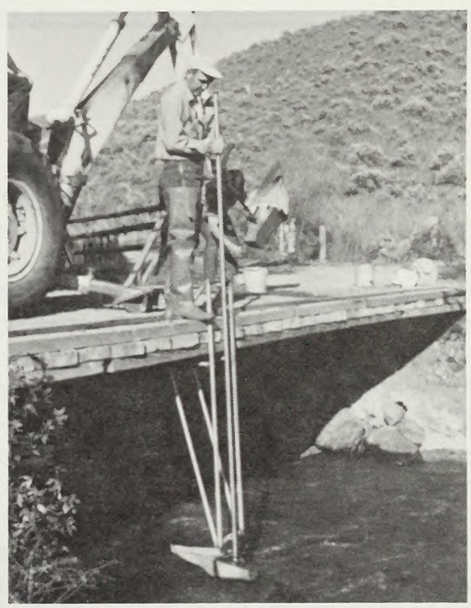
Streambank Erosion

Thunderstorm Erosion - July 1978

A sediment sampling network was initiated in connection with runoff measurements because of visible erosion and stream sediment transport.

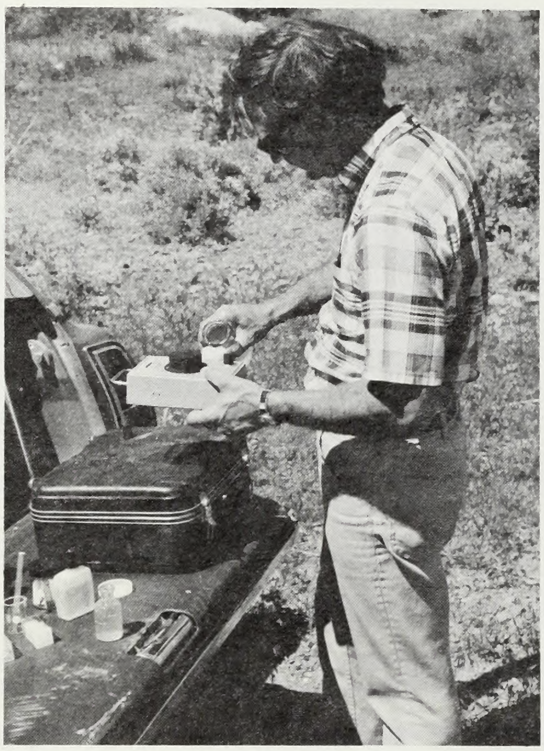
The major objective of the erosion and stream sediment program is to accurately sample sediment transport at key stations and determine sediment yields especially during storms.

The data collected at Reynolds Creek has been used to develop erosion and sediment relationships and to field test many other methods such as the Universal Soil Loss Equation, Pacific Southwest Interagency Committee method, Flaxman Sediment Yield Equation, and the modified Universal Soil Loss Equation.

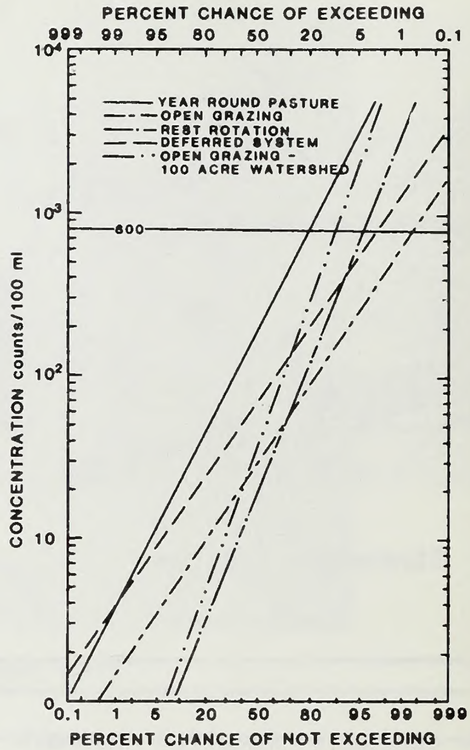


Bedload Sediment Sampling

Water Quality



Field Analysis



Comparison of Grazing Practices

Water quality investigations were initiated in 1972 at the request of BLM for gathering information on assessing potential water quality impacts associated with rangeland livestock operation. The general objective was to determine water quality characteristics as influenced by: 1) livestock operations under various management practices; 2) irrigation return flow; and 3) natural soil, geologic and vegetative conditions. Recommendations for the reduction of nonpoint source water quality impacts favored the general practice of minimizing livestock contact with streams--such as developing upland water sources and placement of mineral and salt supplies considerable distance from streams.

One of the significant findings made during the water quality research was the discovery of atypical E. coli colonies in bacteria samples of rangeland streams. Failure of resource managers to recognize these atypical colonies can lead to significant errors in the estimation of the quality of rangeland streams.

Vegetation and Soils

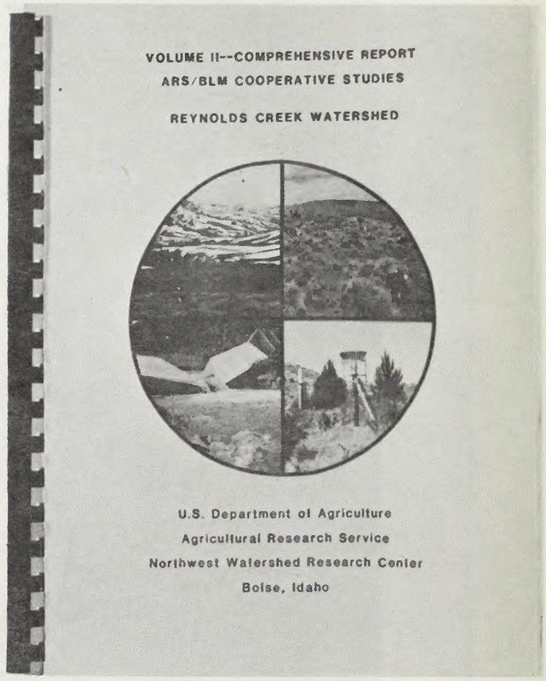
Wyoming Big Sagebrush

Vegetation is one of the few rangeland characteristics sensitive to management that is also an important factor in controlling runoff and erosion. Four major vegetation studies have been conducted on the Reynolds Creek Experimental Watershed. They were: 1) forage production, composition, and cover as affected by the exclusion of grazing; 2) species adaptability plantings; 3) comparison between the wheel-point, step-point, and point-frame cover sampling methods; and 4) herbage response after mechanical and herbicide treatment of big sagebrush.

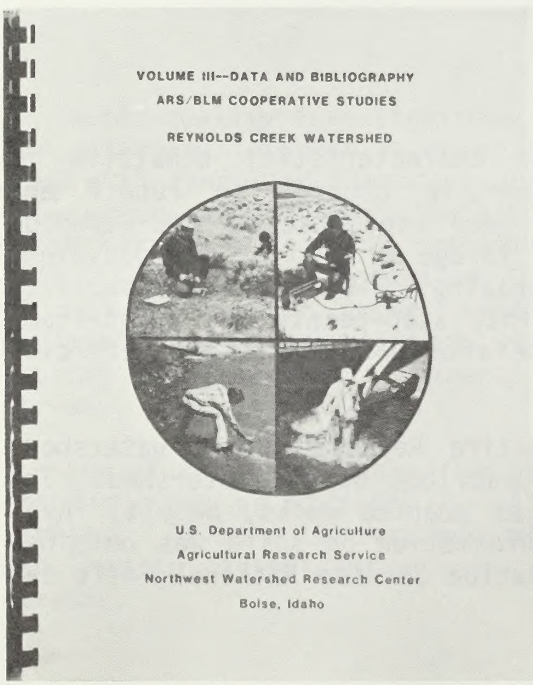
Soils studies have been made over the entire Reynolds Creek watershed. Eight Soil Associations have been mapped and described on the watershed. The soils have formed from parent materials such as granite rocks, basalt, rhyolite, and sedimentary material. Additional information on soils was obtained through cooperative work with the Soil Conservation Service National Soils Lab in 1980-82.

Comprehensive Report

In 1983, the Agricultural Research Service released two reports containing descriptive information, data summaries, and bibliography for the ARS/BLM cooperative studies at Reynolds Creek Experimental Watershed.



Data and Bibliography

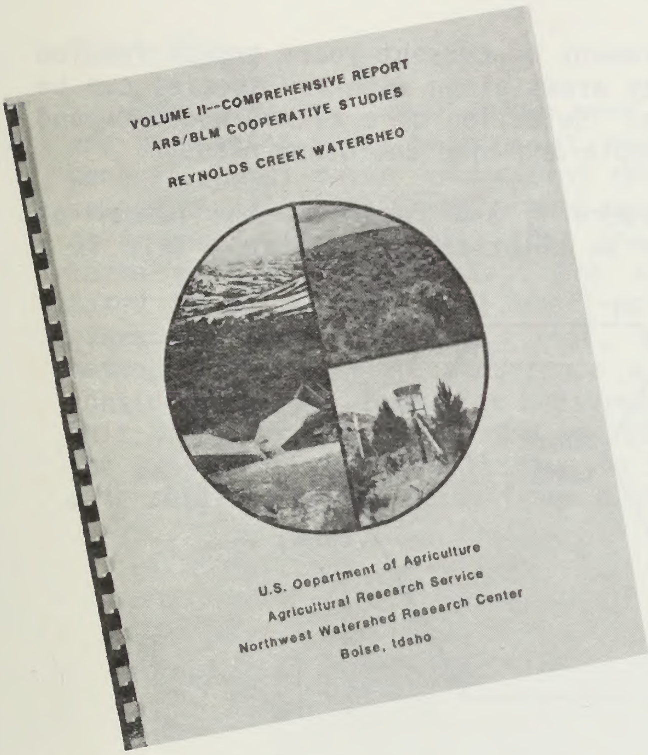


These reports are available from the Northwest Watershed Research Center, Agricultural Research Service in Boise, Idaho or the Bureau of Land Management, Denver Service Center, in Denver, Colorado.

GENERAL SUMMARY

GENERAL SUMMARY

The following general summary will elaborate on the executive summary and the information contained in Volumes II and III. If a reader desires more information, please request Volume II--Comprehensive Report ARS/BLM Cooperative Studies, Reynolds Creek Watershed, and Volume III--Data and Bibliography ARS/BLM Cooperative Studies, Reynolds Creek Watershed available from the Northwest Watershed Research Center, USDA-ARS, 270 S. Orchard, Boise, ID 83705.



Rangeland monitoring can be considered to be a measurement or a forecast (verified by past observations) of a cause and effect relationship. The cause would be an implemented rangeland management plan and the effect is the response in one or more rangeland resource components. On public rangeland, monitoring generally concentrates on the measurement of plant response to management actions.

The four basic factors illustrated in Figure 1 are needed to analyze vegetation response. Managers use the first three measurements--actual use, forage use, and weather--in the short term to adjust the distribution of animals on the range, the season of use, and (if necessary) animal numbers. The fourth measurement (trend) is used over the long term along with the first three.

Forage use is an actual ground measurement of current years growth removed by livestock, wildlife, insects, etc. Key areas along with key species can be observed each year to estimate forage use. Selection of a method would depend on kinds of vegetation, constraints of people and time and other needs.

Actual use generally consists of observing and recording the number of animal units and the duration of time in an allotment or pasture. This is a measure of the management plan input.

Forage use
Use of vegetation by animals

Actual use
Number of animals and length of stay

Weather
Effect on vegetation

Short term

Trend
Changes in vegetation condition

Long term

Figure 1. Four basic rangeland measurements.

Weather, the primary driver of plant growth each year (such as precipitation and temperature) generally needs to be monitored. A particular plant species growth, vigor, and reproduction react strongly to weather conditions. Without a means to correct yearly forage production for that year's weather conditions, evaluations of management impacts would be confounded.

Trend is the principle measurement, predicted or forecasted, whereby the management plan would be judged to be changing vegetation toward or away from climax, or not changing it at all. Indicators of trend include changes in: 1) plant composition, frequency, production, reproduction, and vigor; 2) amount of litter; 3) evidence of erosion; and 4) the percent of ground area protected by plants, litter, and rocks.

Other monitoring information includes factors affecting soil loss, water resources such as springs, streams, soil moisture and groundwater, water quality, riparian zones, fisheries, wildlife, livestock production, and quality of recreation and wilderness values.

Research results reported in the main report (Volume II) are discussed here in terms of their application to the monitoring of forage use, weather, trend and supporting resource information. Actual use is assumed to be a compilation that describes the numerical implementation of the management plan. Two approaches in monitoring are described: 1) the classical method of annual or periodic field measurements to determine a trend; and 2) the potential for utilizing a computerized model to determine a trend.

MONITORING METHODS

Vegetation

Overstory and basal cover were measured by the wheel-point, step-point, and the point-frame methods at several watershed locations (Figure 2). In general, basal cover information obtained by the three methods was about the same with the point-frame method measuring slightly more litter and rock. The differences were so small that the results of this study indicate that the three methods measure about the same basal cover for the sites surveyed. Based on first hits, the wheel-point and step-point methods measured more overstory cover and less litter, rock, and bareground than the point-frame method. Frequency of occurrence as measured by the point-frame method was considerably less than that measured by the wheel-point method. The data from this study indicates that the overstory and frequency of occurrence data from the step-point method will have to be adjusted if the data are compared with data obtained by the point-frame method.

Figure 2. Measuring cover with the point-frame method.

In Volume II, standard sampling procedures are discussed and experiences with them are presented. The extreme variability associated with sampling vegetation is presented. Sample sizes are presented for selected levels of accuracy and confidence. The large variance associated with many of the trend indicators requires unrealistically large sample sizes in order to verify trend existence.

Unless a refinement of statistical procedures, improved sampling designs, or measurement of concomitant factors is possible, the establishment of a trend or lack of a trend will require many years and carefully controlled conditions. It appears feasible to predict production trends with models such as ERHYM and SPUR (see Modeling section). The SPUR model will have the potential to predict trends for species composition. Field measurements for several years at a site would calibrate the model. The calibrated model would then utilize input from management plans and scenarios of generated weather or historical data sequences to predict forage trends.

The application of rangeland resource models to resource monitoring can be a most significant development for BLM resource management and monitoring activities.

Precipitation

Vegetation sampling sites are subject to spatial and temporal variation in weather factors. Precipitation, a principle input to vegetation growth, must either be measured at particular sites, extrapolated from existing weather stations, or estimated by precipitation models.

Reported research on instrumentation, installation and its maintenance make it possible to measure precipitation under conditions of rain, snow, and excessive wind existing at any watershed site. An analysis was made on spacing of gages which would infer the size of area that one gage represents.

The models, given in Volume II, allow one to predict annual and monthly precipitation amounts at a particular site if the site elevation and aspect are known. Required input for making a prediction is precipitation at a base station, such as a valley weather station. A long term series of precipitation amounts can also be predicted by reported models applied to a particular site. The validity of a predicted series can be evaluated by comparison to historical records.

Other weather factors such as temperature, radiation, and evaporation have been measured for a range of elevations. Installation and maintenance of these instruments have also been reported.

Utilizing weather information would depend on the procedures used to establish the presence or absence of weather trends. Weather data can be used to establish an index for a particular sampling site. The series of precipitation and weather factors provides input to productivity models typified by the ERHYM model.

Streamflow and Sediment

Instrumentation for measuring streamflow under adverse conditions has been developed and tested. The extremes of flow, sediment, and bedload material have proved valuable in solving measurement problems. Much of this is discussed in other sections or is referenced in published materials. Base values of these quantities and their statistical properties are reported for the Reynolds Creek watershed. Prediction of similar values for other range sites would require simulation models using validated models for those sites.

Water Quality

The Reynolds Creek research has established that one impact of open range grazing on streamflow quality is increased *E. coli*, if stock water sources are limited to streams. Establishing upland water sources appears to alleviate bacterial pollution. Standard procedures are discussed in the text on water quality laboratory techniques and field sampling procedures.

RANGELAND MODELING

Rangeland resource modeling is the procedure of representing the extremely complex and interactive processes on a rangeland area by a model. If validated by comparison of predictions with observations for a rangeland watershed or site, the model can be used with some confidence to predict the consequences of range management inputs on forage production, water supplies, erosion, and soil water. Such models also have the potential for predicting trends of such indicators as plant composition, herbage yield, and erosion.

The confidence which the range manager has in a model will depend on the ability of the model to predict measured quantities on rangeland areas. The Reynolds Creek watershed provides data sets which are useful for model development and verification. In the following sections, model component testing and evaluation using Reynolds Creek watershed measurements are presented. Also a rangeland productivity model is presented. The reported infiltration model is still under development but represents an enhancement or an alternative to calculating runoff by the SCS curve number approach.

Soil Water Modeling

Soil water modeling provides inputs on the factors affecting the day-to-day soil water status, which in turn modifies vegetation or water availability. The temporal distribution of soil water within the portion of the soil profile that supplies plant roots is a complex interaction of many variables related to present and historical climate, plants, and parent soil materials. Two models were evaluated on their adaptability to rangeland conditions (such as data availability) and their accuracy when compared to measured soil water contents and profile distribution. One of the two soil water balance models represents a relatively simple model and the other a more complex, process oriented model.

The simpler model, named ERHYM (Ekalaka Rangeland Hydrology Yield Model), was originally developed for growing season use on grasslands of the northern Great Plains. It has been modified to extend its applicability to year-round use, to include snow accumulation and melt procedures, and to utilize more user-oriented soil and plant growth parameters. The more complex model, named SPAW (Soil-Plant-Air-Water) was originally developed for use with cultivated crops in the Midwest and for growing season conditions. Somewhat more data is required to use the SPAW model and more assumptions, particularly in the plant growth and stress relationships, are required.

Results indicated that, overall, ERHYM duplicated observed values slightly better than did SPAW, for the two sites investigated. The lack of a snow accumulation and melt routine in SPAW may be the main source of error. This error is more a function of timing, rather than a difference in total soil water at the end of the year, where results for the two models were very similar. The major differences between the two models occurred in the late fall and winter, probably because of the inability of SPAW to account for storage of storm water as snow; and in the spring when greater potential evapotranspiration within SPAW caused earlier extraction of the soil water.

Conclusions from the evaluation of the two soil water balance models were that both models were adaptable to western rangeland conditions and produced results which followed observed trends adequately. The ERHYM model would probably be more appropriate when; 1) there is snowfall and snow water accumulation; 2) plant growth and stress data are not available for the species under investigation; and 3) computer capacity is limited, or cost of computer operation is significant.

Forage Productivity Modeling

ERHYM is a physically-based climate, water-balance model developed to predict annual herbage yield and runoff from northern Great Plains rangelands. ERHYM should be applicable to a wide range of grassland ecosystems, provided the input parameters are adequately defined. As initially developed, ERHYM utilized a single set of soil temperature curves to represent various soil depths in the northern Great Plains. Also, the crop coefficients and transpiration coefficients were based on the vegetation characteristics of the mixed-grass prairie. The purpose of this study was to modify and evaluate ERHYM in terms of forage production application to sagebrush-grass ecosystems using data from the Reynolds Creek Experimental Watershed.

Soil temperature data from the lower elevation sites at Reynolds Creek indicated that soil temperature may not be the critical factor that it was in the northern Great Plains where subsurface soil layers often remained at below freezing temperatures late into May. However, a soil temperature model was interfaced to ERHYM and evaluated. Preliminary results indicated a good relationship between field-measured and model-predicted soil temperatures.

Model-predicted forage yields were compared to field measured yields for the Flats and Lower Sheep Creek study sites. Because of the high variability among yield samples, it was difficult to get reliable yield data for comparison; however, the results indicate the applicability of ERHYM for predicting the peak standing crop yields in sagebrush grassland ecosystems. At the Lower Sheep site there was reasonably good agreement between model-predicted and field-measured yields. The drought in 1977 was well represented by the model. At the Flats site, the model did not perform as well. It has no mechanism to account for influxes of annual cheatgrass that occur at the Flats site but not at the Lower Sheep site. Fall growing conditions play a major role in the yield fluctuations of this annual, and the model as it currently functions does not consider the previous fall conditions. Some modifications are necessary before the model can effectively predict yields on range sites dominated by annual grasses.

The evaluation of ERHYM for sagebrush-grassland range sites does indicate that it can be an effective tool for estimating soil water (Figure 3) and herbage yields. It can effectively index growing seasons as related to plant yield potentials, providing a means of comparing growing conditions among sites and among years.

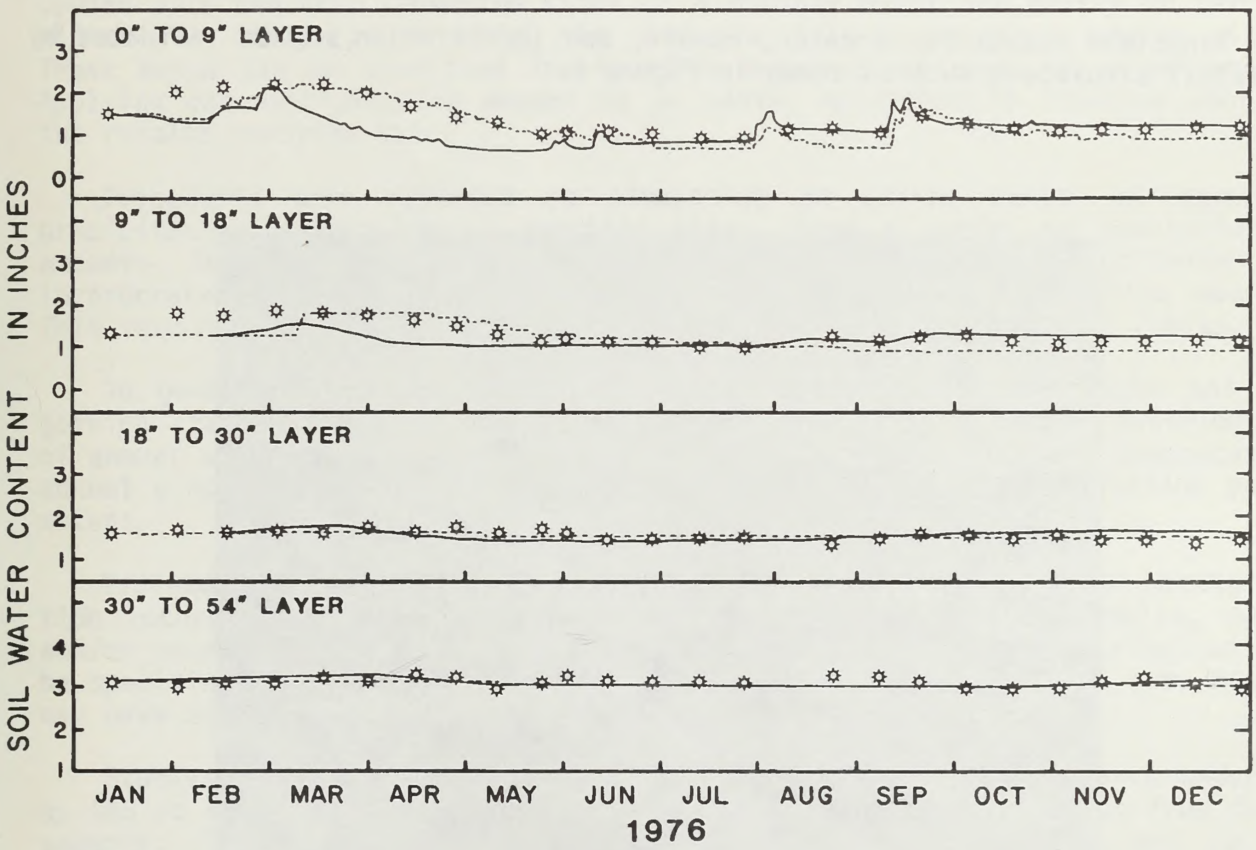


Figure 3. Field measured (*) and model-predicted (SPAW = ERHYM = ----), soil water content for four layers, from the surface to 18 inch depth, with time for 1976 at the Flats site.

Infiltration Modeling

Comparing the widely used SCS curve number procedure for runoff prediction with an infiltration based procedure indicates that the infiltration approach requires much more input data and more complex computation. However, the increasing availability of soils data is making it more feasible especially since the effects of land use can be more rationally evaluated.

The parameters of the Green and Ampt infiltration equation have been related to readily available soils information. Soil texture, soil organic matter and soil porosity (bulk density) were related to the Green and Ampt parameters representing conductivity, available porosity and wetting front capillary potential. Changes in soil porosity such as might be produced by tillage or compaction were derived from available soils data.

The SCS Hydrologic Soil Grouping was defined by the Green and Ampt conductivity parameter. Charts are presented in Volume II from which a soil texture can be defined as A, B, C, or D soil (Hydrologic Soil Groupings) and whereby these groups are related to the Green and Ampt parameters.

Additional research is needed on the influence of coarse fragments on the soil water and infiltration processes. Also, surface crusting and compaction effects on infiltration requires more work.

Rangeland models for erosion, runoff, and infiltration may be validated by rainfall simulators such as shown in Figure 4.

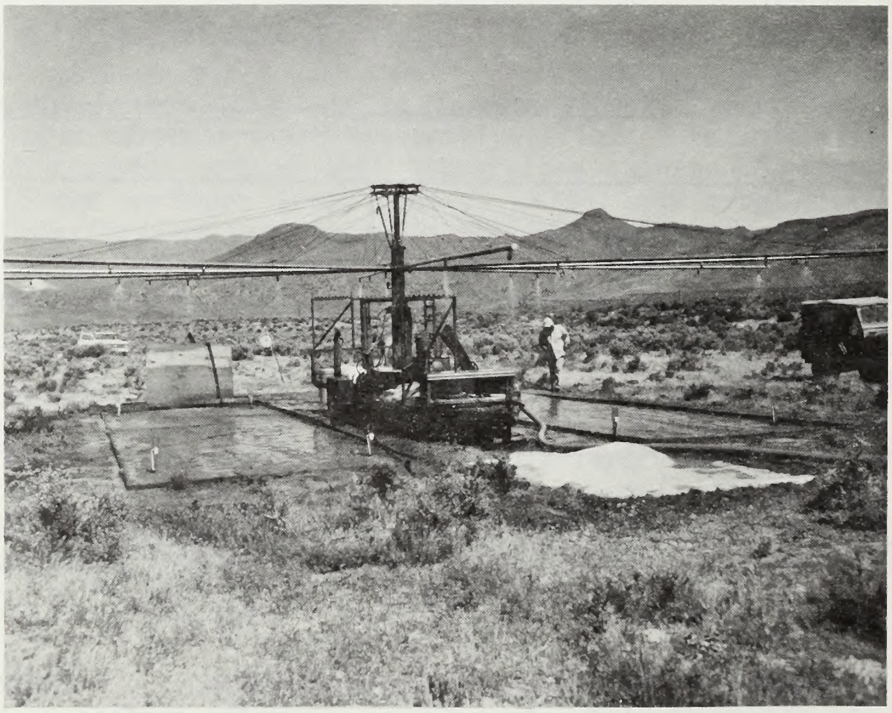


Figure 4. Rotating boom rainfall simulator.

PRECIPITATION

The precipitation network on the Reynolds Creek watershed and 31 other precipitation stations in Idaho and 26 stations in surrounding states provided the data base for developing procedures to predict annual and monthly precipitation amounts. The reported results in the precipitation section (Volume II and III) represent rangeland areas in eastern Washington and Oregon, Idaho, and northern Nevada and Utah. From the analyses of the Reynolds Creek network, the variation of precipitation amounts on a watershed basis was delineated. Average annual precipitation on Reynolds Creek varies from 10 inches to over 40 inches. The change of annual precipitation with elevation is from 8 to 10 inches per 1,000 feet. On a monthly basis the elevation related change varies from 1.3 to 2.0 inches/1,000 feet in January to 0.13 inches/1,000 feet in July.

Elevation and aspect are both significant modifiers of annual and monthly precipitation amounts. Quantitative estimates on a watershed can be made from site elevation and slope aspect. Slope aspect is referenced relative to the direction of predominant storm travel, i.e., upwind or downwind slopes. Equations are reported for predicting mean annual precipitation and mean monthly precipitation as a function of elevation and slope position. On an annual basis downwind precipitation amounts are about 20 percent higher than upwind site amounts. Downwind sites on a monthly basis are nearly 40 percent higher for January, and about the same for July compared to upwind sites. These means can be predicted for specific subareas or zones on a watershed. Applying one precipitation amount to an entire watershed is improved upon by the results reported here.

Procedures were reported on simulating an entire series of expected precipitation amounts for a specific site. From a series of precipitation amounts, the year-to-year or month-to-month variability can be inferred and incorporated into water supply, soil water, and forage production models. This then provides the capability to make forecasts with confidence limits.

To generate an n-year record of annual precipitation for Idaho and adjoining states, equations are presented for specifying a normal distribution of annual precipitation at particular sites. The variability and sequences of annual precipitation are predicted from the derived normal distribution parameters.

Procedures were developed and reported for simulating an n-year precipitation record for each month for Idaho and adjoining states. Tables, maps, and/or equations are presented from which a cube-root-normal distribution can be specified for specific sites and for particular months. Since some months may have zero precipitation, this occurrence is also predicted.

Studies now proposed will simulate daily precipitation. Research underway by ARS at Tucson has the potential to simulate hourly precipitation from daily amounts. These developments will facilitate prediction modeling and use of infiltration in runoff modeling.

Runoff and streamflow data were collected and reported for six subwatersheds or main stem gaging stations for varying time periods between 1963 and 1982. Depending on the elevation, snowmelt accounts for 50 to 85 percent of the mean annual runoff. At highest elevations, snowmelt runoff peaks occur from May to June. Elevation and topography are dominant factors affecting runoff amounts. Corresponding with precipitation patterns on the watershed, higher water yields occur on the southwestern and western slopes. The Reynolds Creek water yield map (Figure 5) indicates that significant water yields occur only when annual precipitation exceeds 14 inches. Above that threshold annual runoff is approximately 75 percent of the annual precipitation. Little runoff occurs below 4250 feet elevation on downwind sites and below 5020 feet on upwind sites.

From the runoff records, annual exceedence values were developed for a range of mean annual runoff values. Thus the availability of an annual runoff volume can be predicted at selected exceedence levels, i.e., 1 percent, 5 percent, etc. In general, the variability of mean annual runoff increases as mean annual runoff decreases.

Streamflow volume-duration of Reynolds Outlet, Macks Creek, Tollgate, and Reynolds Mountain East runoff stations, spanning watershed size and elevation, were characterized by the following statistics:

- Annual maximum runoff volumes for durations of 1, 3, 7, 15, 30, 60, 90, 120, 183, 274, and 365 days;
- Consecutive days of runoff above a threshold of 1, 2.5, 5, 10, 25, 50, 75, 100, 200, and 300 cfs;
- Annual number of days flow is above a threshold of 1, 2.5, 5, 10, 25, 50, 75, 100, 200, and 300 cfs;
- Annual minimum flows (inches) for durations of 1, 3, 7, 15, 30, 60, 90, 120, 183, 274, and 365 days;
- Annual maximum consecutive days that flow is below the thresholds of 1, 3, 5, 7, 10, 15, 20, 50, 100, 150, cfs; and
- Annual number of days that flow is below thresholds of 1, 3, 5, 7, 100, 15, 20, 50, 100, 150 cfs.

Flood analyses are also presented. Annual maximum floods at elevations above 6000 feet are normally from spring snowmelt, while floods below this elevation originate from summer thunderstorms, spring snowmelt, and/or winter rainfall. Winter rainfall on snow and frozen ground can produce severe flooding at low to mid elevations. For example, the winter storm of December 1964 was considered one of the most severe and widespread in the western United States. Water year maximum streamflow and dates of occurrence are reported for four stream stations.

Winter storms accounted for 8 of the 19 annual maximum floods at the Reynolds Creek Outlet (90 sq. mi), 9 of the 18 annual maximum floods at Macks Creek (12.3 sq. mi), but only 1 of the 19 annual maximum at the Reynolds Mountain East station (0.16 sq. mi and elevation 6,600 - 7,000 ft). Severe localized flooding has occurred from thunderstorms at the lower elevations. A peak runoff rate of 250 cfs per square mile (cfm) from a 4.5 square mile area was measured on June 11, 1977. Partial duration flood series were also developed for the four streamflow sites. They provided an indication of severe flooding at each site.

A frequency analysis provided charts giving the streamflow for 2 to 100 year recurrence intervals for instantaneous, 6 hr, 24 hr, 172 hr, and 192 hr flow durations.

A comparison of maximum floods of record at Reynolds Creek with other watersheds in southwest Idaho indicates that the Reynolds Creek records are representative. A tabulation of maximum streamflow is available for rangeland watersheds in southwest Idaho and comparable areas in Idaho, Nevada, and Oregon.

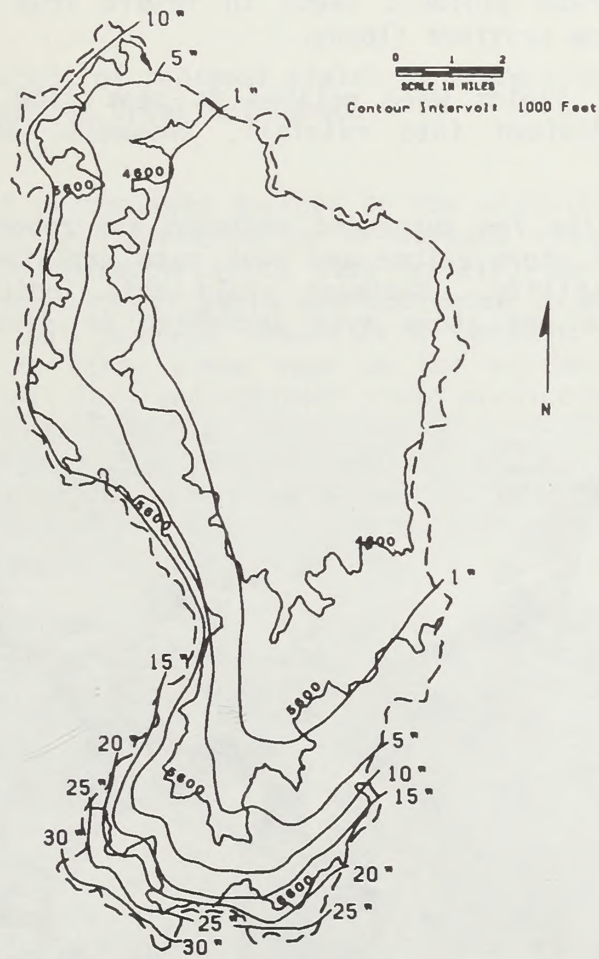


Figure 5. Map of water yield in inches estimated from streamflow records - Reynolds Creek Experimental Watershed.

Sediment sampling stations (Figure 6) were established at runoff measurement sites. The major objective has been to characterize sediment transport and determine yields at watershed stream sites as a function of rangeland watershed characteristics. Extensive efforts were made with existing or with developed equipment to measure coarse bedload material transported by Reynolds Creek. Instrumentation and sampling procedures have evolved with improvements in technology. Standard laboratory procedures were used in all sample analyses.

Highest sediment concentrations are caused by thunderstorms. Maximum concentration and dates of occurrence and the accompanying peak rate are presented in Volume II and III for four Reynolds Creek sites. These are typical of many rangeland watersheds.

Sediment yields have been summarized for the period of record. Bedload appears to be 10 to 20 percent of the total load at stream sites. Small watershed sediment sampling stations have shown lower suspended sediment concentrations than at downstream sampling sites during major runoff events. The additional downstream sediment seems to result from picking up channel sediments deposited from previous floods.

Suspended sediment yields were related to peak flow and runoff volume. Runoff events were divided into rainfall, snowmelt, and mixed rainfall-snowmelt events.

Various relationships for suspended sediment are reported by storm type. An interaction term of storm volume and peak rate explained about 75 percent of the observed variability. Sediment yield data indicate a relationship between sediment yield and storm type according to elevation as shown in Figure 7.

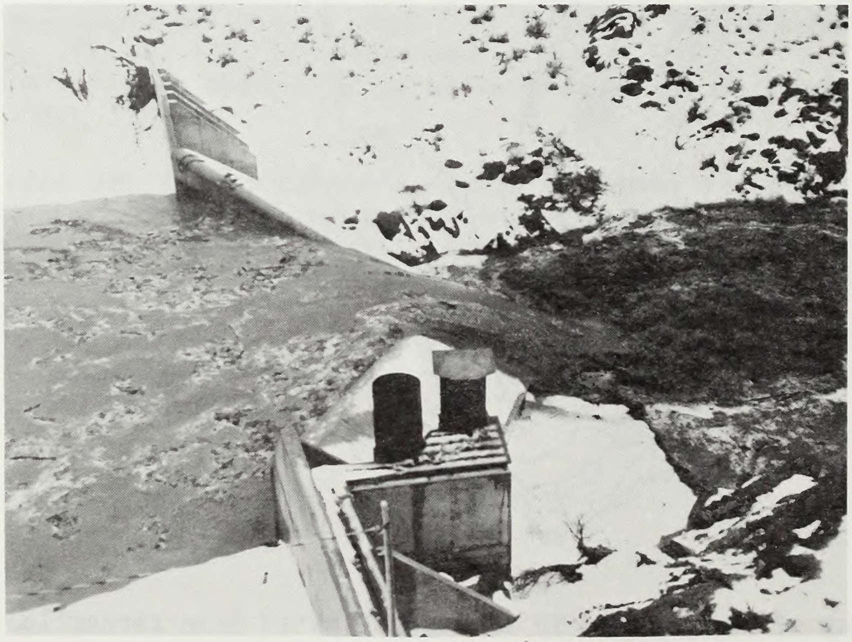


Figure 6. Peak streamflow at Reynolds Outlet Weir, January 31, 1963.

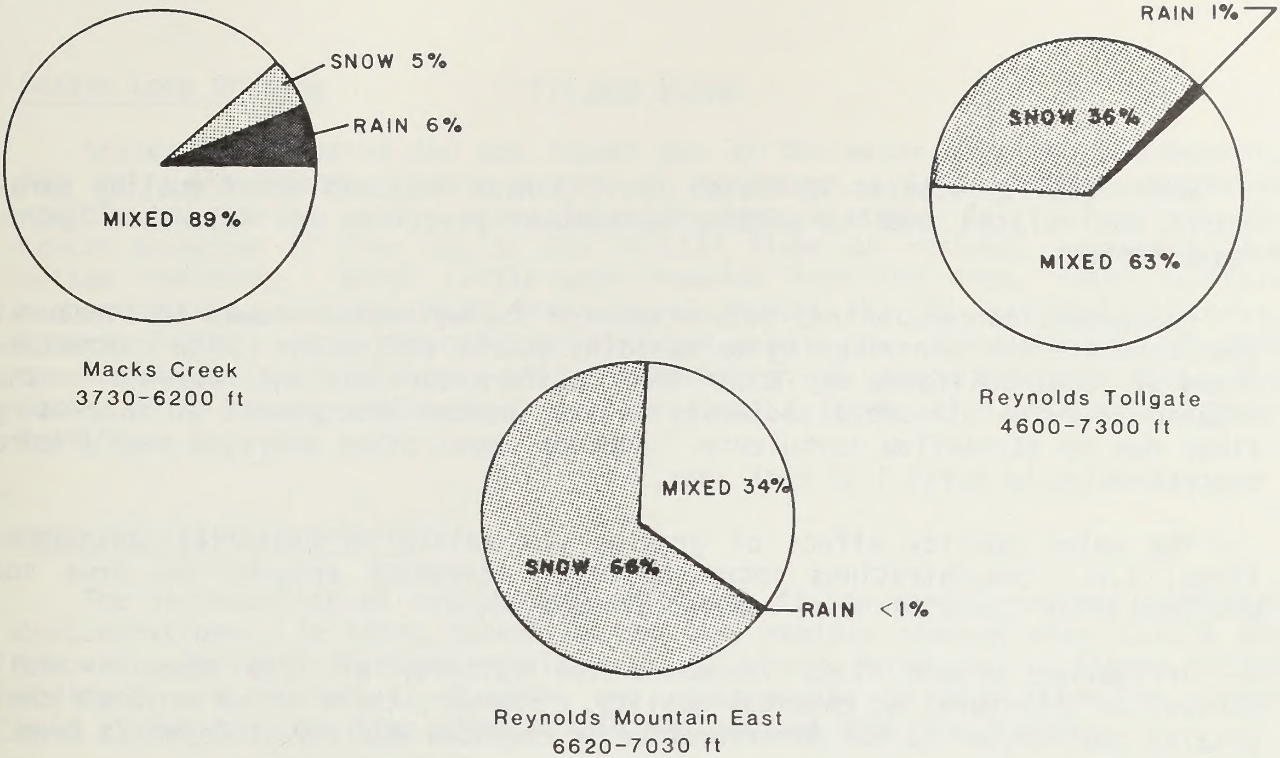


Figure 7. Percent of sediment yields by storm type by elevation - Reynolds Creek Watershed.

The variation of percentages depends on the elevation of the contributing areas. Event runoff transports 60 to 96 percent of stream suspended sediment. Particle-size characteristics vary widely, but transported particle sizes increased in high runoff years and decreased in drought years. Bedload sampling indicates that Reynolds Creek is a sediment limiting stream, contrasted to streams in other areas such as the southwest that are transport limiting. Several soil loss and sediment yield predictions have been tested:

- The Pacific Southwest Interagency Committee (PSIAC) procedure was found to predict sediment yields within 15 percent of measured yields. Management practices such as grazing or brush control can be evaluated by the procedure, but this aspect was not tested; and

- The Modified Universal Soil Loss Equation (MUSLE) showed great potential for predicting sediment yields where mixed rainfall and snowmelt events are common. However, much more study is needed where snowmelt is the major factor. Equation parameters and correlations are presented by watersheds and by type of event in Volume II.

Study is continuing on rangeland application of the Universal Soil Loss Equation (USLE). Rainfall simulation studies have provided input to a study underway by BLM and ARS on adapting the USLE to rangelands. The USLE can provide valuable insights for the manager on how rangeland practices influence soil erosion. Preliminary results indicate that the estimated K-factors (soil erodibility) from the published nomograph compare favorably with values from the simulator data.

Water quality studies initiated in 1972 have measured water quality parameters and related them to grazing management practices and watershed hydrologic factors.

Background concentrations determined for the watershed showed that natural processes are not contributing to nonpoint source pollution. High concentrations of fecal coliforms may occur from coliform survival and regrowth in the organic layer on streambed sediments and may become resuspended at increasing flows due to streamflow turbulence. However, most sites averaged nearly zero concentration by April 1 of each year.

The water quality effect of grazing was mainly in bacterial concentrations, i.e., concentrations increased after livestock entered the area and declined after livestock were removed (Figure 8).

Irrigation return flows increased the salinity of late summer - fall streamflow deteriorating chemical quality. However, there is no evidence that grazing contributes to the deterioration in chemical quality of Reynolds Creek.

Grazing management systems evaluated for impact on water quality were season-long, deferred rotation, rest rotation, and wintering pastures.

Figure 8. Livestock grazing near stream.

Season Long Grazing

Season long grazing did not impact any of the water chemistry parameters. The only significant impact was fecal coliforms. Concentration increased rapidly as soon as cattle moved into the area in early July. A slight increase occurred in June due to the initial flush or residual organisms from bottom sediments. After cattle were removed from the area, fecal coliform concentrations remained high for several months due to residual colonies. Natural factors which reduced concentration were colder temperatures, aeration due to streamflow turbulence, and a distribution of cattle over the area. Any factor which causes cattle to congregate along a stream also increases concentration.

Deferred Rotation Grazing

The introduction of cattle into allotment fields rapidly raises bacterial concentrations. In turn, concentrations are rapidly reduced when cattle are removed. Residual colonies remaining along stream banks and in stream bottom sediments are subject to flushing and resuspension by high-intensity summer rain storms for some time after cattle are removed from the fields.

Rest-Rotation

The water quality characteristics of a rest rotation system were evaluated on a Boise Front area. Again, increases in fecal coliform concentrations reflect the presence of warm blooded animals. In addition to cattle, a band of 2,000 sheep pass through the area every spring and fall and a deer herd in excess of 4,000 winter in the area each year (Figure 9).

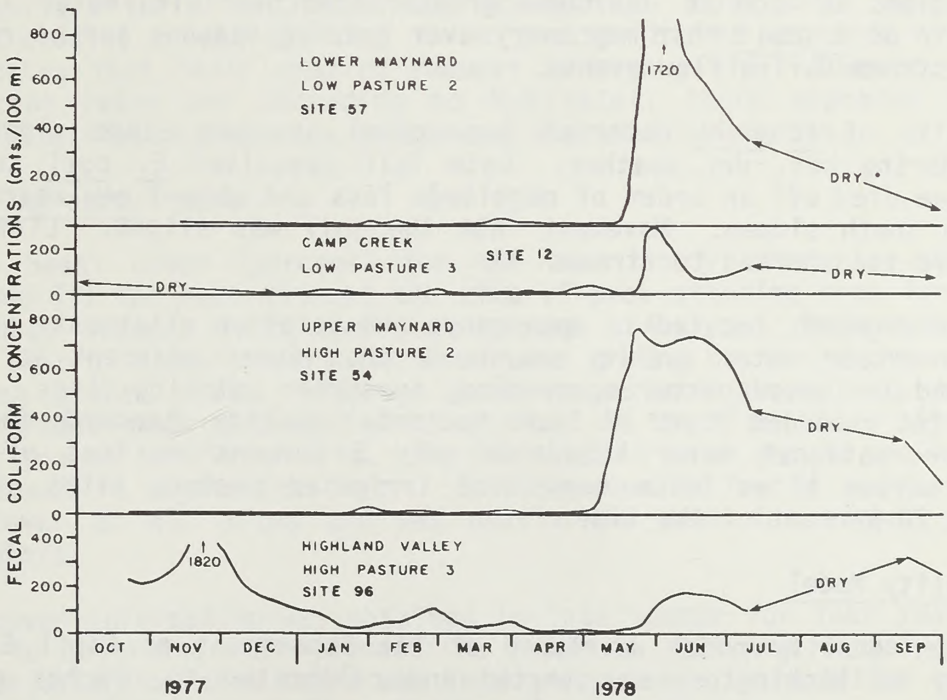


Figure 9. Fecal coliform concentrations reflect grazing of cattle, sheep, and deer.

Winter Feeding Pastures

During the period October through March of each year, approximately 2,000 head of cattle winter on pasture/hay areas along Reynolds Creek. As these areas are free from snow and the soil surface is mostly frozen, they are responsive to winter rainfall/runoff events which, along with irrigation return flow, carry bacteria into Reynolds Creek. A study on this area was completed on wintering pastures in which the stocking rate was varied; i.e., no cattle, 4/ac and 16/ac. Average concentrations, though very high from the normal and 4 and 16 times normal stocking rates, were diluted and filtered by field perimeter vegetation, and the instream concentrations were reduced significantly. Runoff from these pastures also exhibited high bacterial concentrations.

Alternative Water Sources

Evidence was documented that spring-water development in the deferred rotation unit is a successful management tool for reducing instream fecal coliform concentrations.

Selective Phenomena

Cyclic variation of bacterial concentrations was identified as related to sunlight exposure. During night time and in shaded stream locations, the concentrations increased. Direct sunlight sites had reduced concentrations.

Increased streamflow increased bacterial concentrations up to a limit. Above that limit, increased streamflow diluted the bacterial content and reduced the concentration.

Bottom sediments are a substantial source of *E. coli*. These sediments had concentrations as much as 700 times greater than overlying waters. These are a reservoir of *E. coli* that may carry over grazing seasons and be reintroduced into the stream during flow events.

Deposits of *E. coli* material (cow pies) on open range sites died off rapidly during hot, dry weather. Late fall deposited *E. coli* subjected to freeze-thaw died off an order of magnitude less and showed new regrowth in the spring on south slopes. Movement into the soil was slight. Little of this material is transported to streams.

Stream segments located in open range and rotation allotments are far less likely to exceed water quality standards than those adjacent to winter and year-around irrigated pastures, or along in-stream watering sites. Open range stream sites exceeded State of Idaho bacterial quality standards for Secondary Contact recreational water standards only 5 percent or less of the time. However, stream sites below heavy use irrigated pasture sites exceeded the standards 20 percent of the time.

Water Quality Model

A water quality model developed at the Department of Civil Engineering, University of Washington, was tested and calibrated to reaches of Reynolds Creek. Experience with the model indicates that acceptable simulations of water temperature, dissolved oxygen, and BOD can be produced. Modeling of bacterial concentrations in flowing streams is very difficult and has not been satisfactorily accomplished by any existing model.

VEGETATION AND SOILS

Nine vegetation study sites were located on the Reynolds Creek Watershed. Site elevations ranged from 3885 feet to 6840 feet with annual precipitation ranging from 9.34 inches to 40.91 inches. At some sites drifting snow further increased available water. Soils at sites varied from a loam to gravelly loam.

Fenced exclosures were established at each study site. The area around each site was grazed as part of the existing allotment or pasture. Cages were randomly located on grazed areas. Procedures for estimating yield, and basal and canopy cover are described in the main report.

Grazed and Ungrazed: Herbage Yield

Total herbage yield and yield excluding shrub herbage are reported. Total yield on ungrazed sites ranged from 533 lbs/ac to 1743 lbs per acre. Low yield sites correspond to average annual precipitation of less than 14 inches on south facing slopes where snow is blown off.

Differences in mean annual total herbage yield between grazed and ungrazed treatments were statistically significant at only one site. Year-to-year variations were very large.

Annual mean nonshrub yield was measurably greater on the ungrazed plots than on the grazed plots at two of nine sites. Shrub yield tended to be higher on grazed areas. After 11 years of study, no trends toward greater or lesser nonshrub herbage yield within or outside of exclosures were substantiated.

On one site (Nettleton), excessively heavy grazing was established from 1971 through 1979 for a controlled ten day period. Both total herbage yield and yield excluding shrubs appeared to be greater in the ungrazed area. This trend indicates that heavy grazing reduces herbage yield. However, at sites where stocking rates are according to BLM rates, there appeared to be no herbage yield difference between grazed and ungrazed treatments.

Grazed and Ungrazed: Cover

Average basal cover (percent) for the nine study sites is reported in Volume II and III for each site at the time of peak standing crop for grasses, forbs, shrubs, litter, rock, and bare ground. Analyses indicated somewhat more grass cover, litter cover, and less bare ground on the ungrazed than on the adjacent grazed plots. Average percentage bare ground was measurably greater on grazed than nongrazed plots at four of the nine study sites and at the heavily grazed Nettleton site. An increase in bare ground was associated with a decrease in vegetation cover. Forbs accounted for 11 percent or less of basal cover at all sites and was nearly the same for either grazed or nongrazed plots.

Basal cover information was obtained in late summer for four years at the nine sites to determine cover conditions prior to fall and winter precipitation. These data show that there was less grass cover, more litter cover, and less bare ground in the fall than at peak standing crop.

Basal and First Hit Canopy Cover of Selected Species

No measurable changes in species composition have developed due to non-grazing except on the heavily grazed Nettleton plot. The cheatgrass basal cover was greater on the ungrazed plot and Sandberg bluegrass cover was greater on the grazed plot. Bottlebrush squirreltail was greater on the ungrazed plot than on the grazed plot, but ground cover was about the same. Forb and brush cover did not show a trend at any site.

Frequency of Occurrence

The occurrence values of only the ungrazed plots are discussed. Bottlebrush squirreltail at the lowest elevation site showed an increase especially during the last three years. At the heavily grazed site (Nettleton), Sandberg bluegrass decreased and Bottlebrush squirreltail increased. On the Reynolds Mountain site, brome and forbs increased after a winterkill of big sagebrush.

Plant Nurseries

Nursery sites at three elevations were established in 1974 and 1975 in cooperation with the USDA, Forest Service, Intermountain Forest and Range Experiment Station. Portions of existing exclosures were used. Each year ratings were made to establish plant survival and yearly growth rates. Principle species to survive and grow at each site were rated and summarized in 1981, seven years after seeding. Plants performing well and most promising species are presented in a table with detailed discussion in the text.

Mechanical and Herbicide Treatment

Published work on these treatments indicated that grasses made up a higher percent of the total yield in the treated plots.

Soils Information

The initial second order soil survey of the Reynolds Creek watershed was completed by the Soil Conservation Service (SCS) in 1966. The SCS will re-survey (order 1) the watershed in 1983-84 according to the most recent Soil Taxonomy.

Detailed soil descriptions and laboratory analyses have been completed at a number of watershed sites. Soil and soil-water properties of most important watershed soils are available.

AVAILABILITY OF RESOURCE DATA AND PUBLICATIONS

Data summaries by years and/or months are presented for precipitation, runoff, soil water, soil properties, vegetation characteristics, and water quality parameters in Volume III.

Data inventories are also presented for precipitation, runoff, suspended sediment, temperature, wind, pan evaporation, soil water, solar radiation, water quality, and vegetation data. They are available either on magnetic tapes or on printed forms. Some data sets may still be available only as unprocessed charts. In such cases, special data requests must be considered on an individual basis.

Publications authored by project personnel are listed according to subject area. In most cases, copies or reprints are available upon request.

For each year of BLM-ARS cooperative research, an interim report was prepared and submitted to BLM, Denver Service Center, reporting on annual work plan accomplishments. The comprehensive report (Volume II) draws upon these reports but is mainly limited to finalized findings, whereas material in the interim reports was tentative and/or reports progress on continuing research.

Special reports were submitted to BLM on Water Quality, Frail Lands Hydrology (Rabbit Creek watershed), and on Boise Front studies.

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